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EVALUATION OF COMMERCIALLY AVAILABLE AQUEOUS BATCH IMMERSION CLEANING PRODUCTS

by

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10 January 1996

Aerospace Materials Division
Air Vehicle and Crew Systems Technology Department
Naval Air Warfare Center Aircraft Division
Patuxent River, Maryland

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With the production of Class I Ozone Depleting Substances scheduled to cease in January 1996, it has become necessary to identify suitable replacements for chlorofluorocarbon (CFC-113, Freon 113) vapor degreasing operations currently used to clean avionics components in Navy aircraft maintenance facilities. In this study, one potential option, the use of aqueous cleaning agents, was explored. Commercially available industrial aqueous cleaning agents were evaluated for cleaning capability on simulated operational soils and effects on aircraft materials. Two cleaning agents, Armakleen 2001 and Crest ABS 901, were recommended as a result of this work, and a Military Specification was drafted outlining performance requirements.

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ABSTRACT

With the production of Class I Ozone Depleting Substances scheduled to cease in January 1996, it has become necessary to identify suitable replacements for chlorofluorocarbon (CFC-113, Freon 113) vapor degreasing operations currently used to clean avionics components in Navy aircraft maintenance facilities. In this study, one potential option, the use of aqueous cleaning agents, was explored. Commercially available industrial aqueous cleaning agents were evaluated for cleaning capability on simulated operational soils and effects on aircraft materials. Two cleaning agents, Armakleen 2001 and Crest ABS 901, were recommended as a result of this work, and a Military Specification was drafted outlining performance requirements.

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INTRODUCTION

Due to the imminent discontinuation of the production of Class I Ozone Depleting Substances (ODS), it has become necessary to identify suitable replacements for CFC-113 (Freon 113) vapor degreasing operations currently used to clean avionics components in Navy aircraft maintenance facilities. CFC-113 has been used widely in degreasing operations for avionics or electronics. It's effectiveness as a cleaning agent, low surface tension, and compatibility with materials made it the solvent of choice. There is currently not a "drop-in" replacement available, but many alternative products have been developed or identified that can be adequate substitutes. These replacement products generally fall into one of three categories: solvent, semiaqueous, and aqueous. Each of these classes of cleaning agents has certain advantages and disadvantages associated with its use.

Solvent cleaners typically have the advantage of excellent cleaning capability, compatibility with metallic components, low surface tensions for penetrating small spaces, and high evaporation rates for quick drying. One problem encountered with the use of solvent materials is that most solvents are classified as Volatile Organic Compounds (VOC's) and are subject to air emissions regulations. Additionally, solvents cannot be disposed of through water treatment facilities; therefore, other provisions must be made. Some common options for solvent waste disposal are incineration or reuse as a fuel, distillation to recover usable solvent, or removal by a hazardous waste disposal specialist. Another concern with the use of solvents is a potential affect on plastics and elastomers. Problems encountered may include swelling, degradation, or absorption and postprocess out-gassing of solvent.

Aqueous products typically have the advantage of being environmentally friendly and can sometimes be treated in existing waste-water facilities. They also are generally compatible with plastics and elastomers. However, one concern with aqueous materials is their lower effectiveness in the removal of nonpolar soils as compared to pure solvent materials. Another important concern with the use of aqueous products is their potential for corrosion of metallic components. Finally, with aqueous materials, it is necessary to rinse and dry the parts after cleaning. This may result in a considerable increase in process time for parts with complex geometry.

Semiaqueous products are intended to combine the superior soil removing capability of solvents with the minimal environmental effects of aqueous cleaners. Unfortunately, the disadvantages of both materials are combined also; these products will still often contain high percentages of VOC's, require treatment as hazardous waste, and require water-rinse and drying steps in the process.

The best type of product will likely be application specific; therefore, a single study cannot hope to recommend solutions for all cleaning or maintenance situations. Since aqueous cleaners are normally preferred from an environmental standpoint, these were chosen for evaluation in this study. The chief concerns to be addressed with these types of products were cleaning capability and effects on metallic components.

EXPERIMENTAL

Suppliers of products evaluated in this study are listed in the appendix A. Unless otherwise specified in the specific test method, products were evaluated at the recommended use strength; diluted 1:10 with distilled, de-ionized water. This was based on the majority of the manufacturers' recommendations for normal cleaning applications. Tests were performed as follows:

a. Cleaning capability. Nine stainless steel panels of the dimensions specified in figure 1 were wiped with acetone, allowed to air dry, and weighed to ±0.0001 g. Each of the following soils were applied to three of the panels using a Fisher-Payne dip-coater: MIL-C-81309 (corrosion preventive compound), MIL-H-83282 (hydraulic fluid), and MIL-H-83282 + 10% carbon black (Raven 1040). Soiled panels were baked at 105°C for 1 hr in a forced-draft oven and again weighed to ±0.0001 g. Panels were cleaned for 5 min in 400 ±25 ml of diluted cleaning solution (1:10) maintained at 140 ±5°F using a dip rate of 20 ±1 cycles/min with the apparatus shown in figure 2. Panels were each rinsed for 1 min in distilled, de-ionized water using the same apparatus and method. Panels were allowed to dry in ambient air to constant weight for final weighing. Cleaning efficiency was calculated as the percentage of soil removed by weight, as follows:

$$CE = \frac{w_s - w_f}{w_s - w_i} \times 100$$

where: CE = cleaning efficiency, %
w_i = initial weight, g
w_s = soiled weight, g
w_f = final weight, g

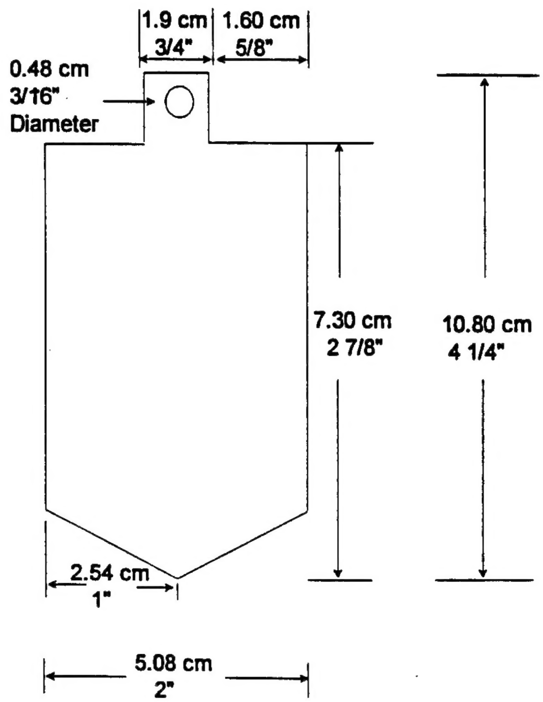

Figure 1
STAINLESS STEEL TEST PANELS

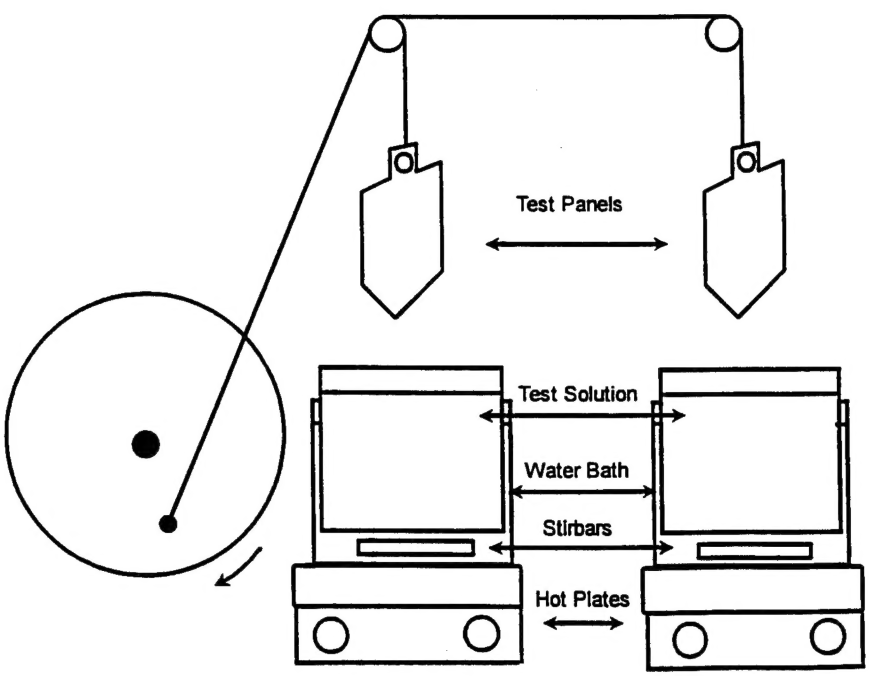

Figure 2
TEST APPARATUS

b. Corrosivity. Corrosivity was determined for cleaning products at recommended use dilution (1:10) according to ASTM F 483, Total Immersion Corrosion Test for Aircraft Maintenance Chemicals, for all metals with the exception of tin/lead (60/40) solder. Solder specimens were coiled (1 in. diameter coils) 8 in. lengths of 1/8 in. diameter solder, and exposed to the test fluid for 24 hr. All corrosion results were the average of three specimens and were calculated as follows:

$$C = \frac{w_i - w_f}{A * t}$$

where: C = Corrosion, μg/cm²/day†
w_i = initial weight, μg
w_f = final weight, μg
A = surface area, cm²
t = time, days

†These units chosen instead of traditional units of mg/cm²/day to simplify presentation in table 2.

c. pH. The pH of the concentrated cleaning solution was measured with a Fisher Accumet model 15 pH meter to ±0.01 pH units.

d. Stability. Samples of concentrated cleaning solution were held for 1 hr at 120 ±2°F and 0 ±2°F and examined for evidence of separation. In addition, the cleaner was mixed 1:10 with 10-grain hard water (0.20 g calcium acetate monohydrate + 0.14 g magnesium sulfate heptahydrate in 1 liter of distilled water) and examined for separation or precipitates.

e. Foam. 100 ±1 ml of use dilution cleaner was heated to 140 ±2°F and mixed in a Waring blender at 8,000 ±1,000 RPM for 2 min, then allowed to settle for 6 min. Final volume of liquid plus foam was then recorded to within ±25 ml.

f. Polyimid Wire. A 24 in. length of polyimid-insulated (Kapton) wiring conforming to MIL-W-81381 was coiled in a double loop and placed in a 4 oz jar containing enough concentrated cleaning solution to completely cover the coil. The jar was stored at room temperature (75 ±5°F) for 14 days. The coil was rinsed and dried, then wrapped and reverse wrapped on a 1/8 in. diameter mandrel. The wire was the subjected to a 1 min dielectric test of 2,500 V in a 5% sodium chloride solution and examined for breakdown or leakage.

RESULTS AND DISCUSSION

Average cleaning efficiencies for each product, along with the 90% confidence intervals (t-distribution) of the averages, are listed in table 1 and shown in figure 3. Some of the calculated cleaning efficiencies were greater than 100%. This is presumed to be because of the slight weight loss due to corrosion of the panels during the cleaning test. Suggested minimum cleaning efficiency requirements and recommended products are shown in boldface. Minimum cleaning efficiency requirements were developed to include top performers that were also compatible with materials.

Table 1
PERCENT CLEANING EFFICIENCY OF AQUEOUS CLEANING PRODUCTS

Product	**MIL-C-81309**		**MIL-H-83282**		**10% Carbon**	
	Avg	**90% CI**	**Avg**	**90% CI**	**Avg**	**90% CI**
LOWER LIMIT	**95**		**90**		**10**	
MIL-D-16791	107	± 9	89	± 4	20	± 2
MIL-C-85570, Ty II	92	± 2	51	± 18	25	± 23
Armakleen E-2001	**97**	**± 1**	**98**	**± 4**	**25**	**± 12**
Basic-H	103	± 2	104	± 1	22	± 7
Blue Gold	103	± 5	99		21	± 8
Branson GP	101	± 2	92	± 4	29	± 7
Brulin 815 GD	103	± 2	99	± 1	19	± 3
Crest ABS 901	**105**	**± 3**	**95**	**± 5**	**49**	**± 8**
DuBois Hi-Tron	99	± 2	96	± 1	17	± 4
Ecomate	102	± 5	14	± 21	5	± 2
Fine Organic 2213	80	± 22	82	± 20	34	± 12
Hurrisafe	101	± 3	99	± 1	23	± 2
MacDermid ND-7	101	± 2	99	± 1	56	± 12
Metalube 4U	103	± 3	99	± 2	84	± 10
Mirachem 500	95	± 1	35	± 4	14	± 7
PolySpray-Jet 790	95	± 5	70	± 8	24	± 7
Preferred B&T	131	± 19	74	± 13	12	± 2

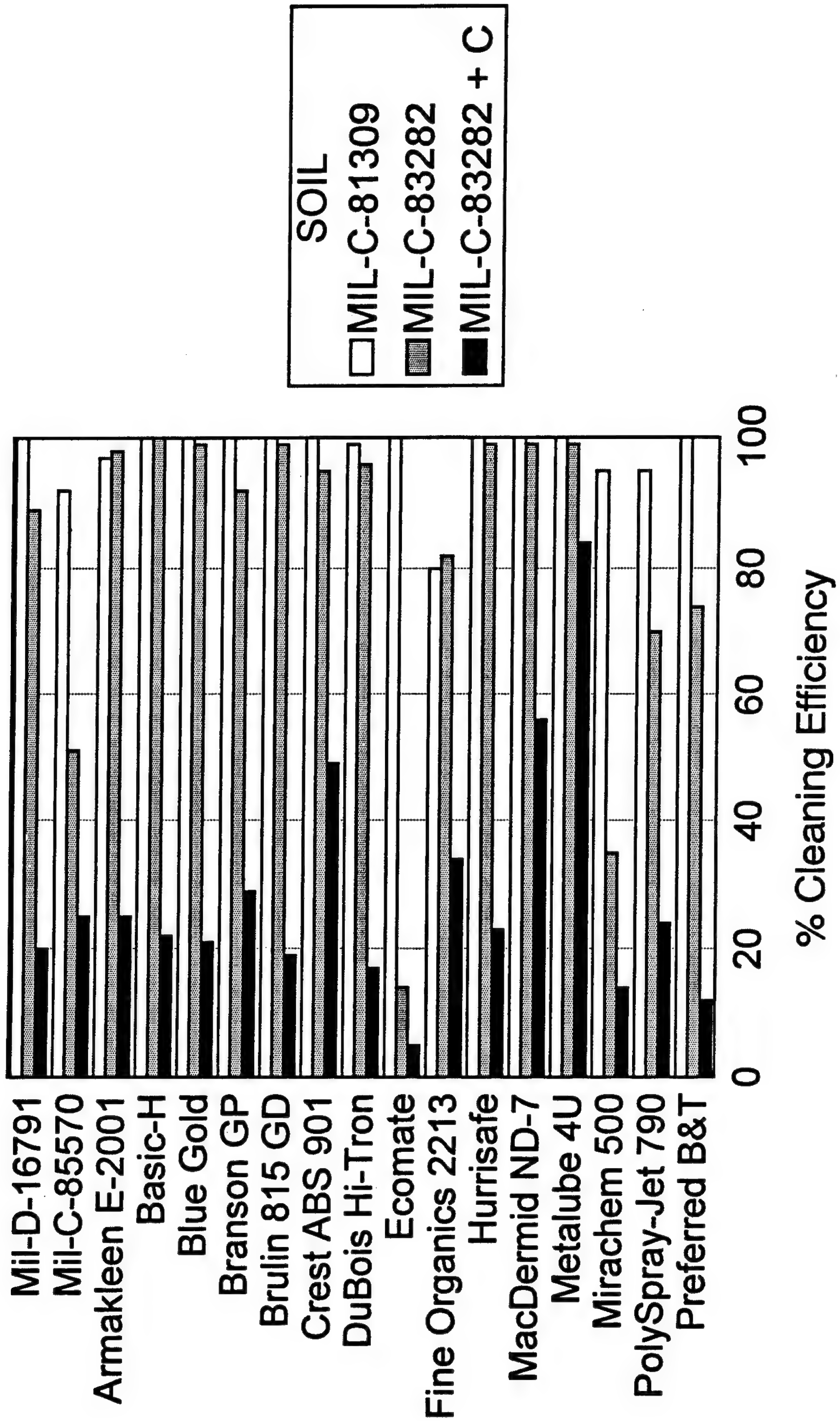

Figure 3
PERCENT CLEANING EFFICIENCY OF AQUEOUS CLEANERS

Table 2 lists average Total Immersion Corrosion results for each product, along with 90% confidence intervals (t-distribution) of the averages. Products performing poorly in the cleaning or corrosion tests were not tested further. Suggested corrosion limits were based on typical limits for aircraft maintenance chemicals, such as those required in MIL-C-85570. The corrosion limit for steel was determined based on the best attainable levels demonstrated by the products tested. Armakleen E-2001 and Crest ABS 901 were both within suggested limits for all metals tested and performed well in the cleaning evaluation. It is significant to note that MacDermid ND-7 and Metalube 4U performed very well in the cleaning evaluation, but are not recommended due to effects on tin/lead solder and copper, respectively. These are considered to be critical materials for the intended application of avionics cleaning. MIL-C-85570 Type II was not tested for corrosion in this study, but conforms to the suggested limits for 2024 aluminum, cadmium, magnesium, steel, and titanium as a requirement of the specification.

Table 3 lists additional tests performed on the cleaning products, with reasons for elimination from consideration indicated where applicable. No criteria was specified for foam levels, as it is expected that equipment used with these materials will be of the batch immersion or ultrasonic type, and will not cause excessive foaming problems. Foaming results are given, however, in the event that this information is desired. Product pH is normally limited to 10.0 for aircraft maintenance chemicals due to the effect of high pH cleaners on Polyimid wiring. Armakleen E-2001 has a pH of 10.8 and, when tested in the concentrated form, caused a slight effect on the exterior insulation of polyimid wire, but did not cause breakdown or leakage. The armakleen product in the recommended use dilution did not have any effect on the polyimid wiring. Since the product is intended to be used in the diluted form, the minor effect of the concentrate on the wiring should not eliminate this product from consideration. Furthermore, a similar minor effect has been observed with distilled, de-ionized water when tested in this manner.

Table 2
TOTAL IMMERSION CORROSION RESULTS FOR AQUEOUS CLEANING PRODUCTS, μg/cm²/day

Product	2024 Al[1]	7075 Al[2]	Cd[3]	Cu[4]	Mg[5]	Steel[6]	Solder[7]	Ti[8]
UPPER LIMIT	**40**	**40**	**200**	**40**	**200**	**100**	**40**	**40**
MIL-D-16791	112 ± 21	36 ± 0	28 ± 8	10 ± 2	86 ± 6	150±5	4±7	2±1
MIL-C-85570, Ty II	<40	ND	<200	ND	<200	<40	ND	<40
Armakleen E-2001	**21 ± 2**	**2 ± 1**	**1 ± 0**	**5 ± 0**	**59 ± 2**	**86±1**	**0±0**	**0±0**
Basic-H*	10 ± 2	4 ± 1	8 ± 0	17 ± 1	139 ± 4	164±3	1±1	2±0
Blue Gold	3 ± 0	8 ± 0	ND	25 ± 0	100 ± 13	84±4	208±12	ND
Branson GP	5 ± 1	10 ± 1	22 ± 7	5 ± 1	68 ± 1	ND	154±30	-1±0
Brulin 815 GD	ND	3 ± 0	70 ± 14	ND	255 ± 5	86±7	51±12	1±0
Crest ABS 901	**19 ± 3**	**23 ± 6**	**-20 ± 4**	**29 ± 1**	**80 ± 3**	**67±4**	**21±1**	**1±0**
DuBois Hi-Tron	1 ± 0	3 ± 0	ND	89 ± 2	82 ± 4	106±1	ND	ND
Ecomate	ND	ND	ND	ND	ND	ND	ND	ND
Fine Organic 2213	ND	ND	ND	ND	ND	ND	63±2	ND
Hurrisafe	6 ± 0	11 ± 1	ND	7 ± 0	110 ± 18	93±5	157±6	1±1
MacDermid ND-7	3 ± 0	5 ± 0	ND	28 ± 3	ND	90±3	228±5	1±0
Metalube 4U	3 ± 0	6 ± 0	ND	192 ± 8	44 ± 17	97±2	ND	ND
Mirachem 500	ND	ND	ND	ND	ND	ND	22±8	ND
PolySpray-Jet 790	ND	ND	ND	ND	ND	ND	20±7	ND
Preferred B&T	ND	ND	ND	ND	ND	ND	ND	ND

ND - Not Determined
*Basic-H failed due to phase separation of the product during testing
[1]2024 aluminum, bare (QQ-A-250/4)
[2]7075 aluminum, bare (QQ-A-250/12)
[3]1020 steel (MIL-S-7952), cadmium plated according to QQ-P-416
[4]Copper (QQ-C-502)
[5]AZ31B-H24 magnesium (QQ-M-44)
[6]1020 steel (MIL-S-7952)
[7]Tin/lead (60/40) solder (QQ-S-571)
[8]6A14V Titanium (MIL-T-9046)

Table 3
VARIOUS TESTS OF AQUEOUS CLEANING PRODUCTS AND REASONS FOR ELIMINATION

Product	Failures	pH	Stability 120°F	Stability 0°F	Foam (ml)	Hard Water Stability	Polyimid Leakage
MIL-D-16791	Al, Steel	7.2	ND	ND	ND	ND	ND
MIL-C-85570, Ty II	Cleaning	8.7	Pass	Pass	600	Pass	ND
Armakleen E-2001	-	**10.8**	**Pass**	**Pass**	**100**	**Pass**	**None†**
Basic-H	All Corrosion	ND	ND	ND	ND	ND	ND
Blue Gold	Solder	12.2	Pass	ND	200	ND	Severe
Branson GP	Solder	12.4	Pass	ND	700	ND	None
Brulin 815 GD	Mg, Solder	11.3	Pass	ND	300	Pass	Moderate
Crest ABS 901	-	**9.6**	**Pass**	**Pass**	**300**	**Pass**	**None**
DuBois Hi-Tron	Steel, Cu	11.9	Pass	ND	100	ND	ND
Ecomate	Cleaning	10.2	Pass	ND	500	ND	ND
Fine Organic 2213	Solder	8.7	ND	ND	ND	ND	ND
Hurrisafe	Solder	11.8	ND	ND	300	ND	ND
MacDermid ND-7	Solder	12.1	ND	ND	300	ND	ND
Metalube 4U	Cu	12.2	ND	ND	600	ND	ND
Mirachem 500	Cleaning	9.0	ND	ND	600	ND	ND
PolySpray-Jet 790	Cleaning	12.5	ND	ND	ND	ND	ND
Preferred B&T	Cleaning	ND	ND	ND	ND	ND	ND

†Caused slight deterioration of the exterior insulation layer

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RECOMMENDATIONS

Crest ABS 901 and Armakleen E-2001 are recommended, mixed in the ratio 1:10 with water, for batch immersion cleaning of avionics components not harmed by water to remove operational fluids and soils. A Military Specification has been drafted to cover these materials and is awaiting approval.

The addition of heat (140°F) and ultrasonics is recommended to boost cleaning ability; however, the U.S. Navy does not currently allow the use of ultrasonics to clean printed circuit boards.

Avionics components cleaned with aqueous cleaners must be rinsed well with water and dried. The recommended drying procedure for printed circuit boards is to blow off rinse residue using dry, contaminant-free air of less than 10 psi and drying in a forced-draft oven at 130°F for 1 hr.[1]

REFERENCE

1. NAVAIR 01-1A-23, Section 006 00, pp. 6-7.

APPENDIX A
SUPPLIER INFORMATION

Product	Supplier	Address
Armakleen E-2001	Church and Dwight	5901-B Peachtree Dunwoody Dr. Atlanta, GA 30328 (404) 396-7227
Basic-H	Shaklee	N/A
Blue Gold	Modern Chemical	P.O. Box 368 Jacksonville, AK 72076 (501) 988-1311
Branson GP	Branson	Eagle Road Danbury, CT 06810-1961 (203) 796-0400
Brulin 815 GD	Brulin	P.O. Box 270 Indianapolis, IN 46206 (800) 776-7149
Crest ABS 901	Crest Ultrasonics Corp.	104 Evergreen Drive Downingtown, PA 19335 (215) 873-9775
DuBois Hi-Tron	DuBois Chemicals	3630 East Kemper Rd. Sharonsville, OH 45241 (513) 554-4200
Ecomate	SOQ Environmental	P.O. Box 41207 Mesa, AZ 85274-1207 (602) 966-2892
Fine Organic 2213	Fine Organics	205 Main Street, PO Box 687 Lodi, NJ 07644-0687 (201) 472-6800
Hurrisafe	Hurrisafe	7307 MacArthur Blvd., Ste. 215 Bethesda, MD 20816 (301) 320-9100
MacDermid ND-7	MacDermid	245 Freight St Waterbury, CT 06702 (203) 575-5700
Metalube 4U	Metalube	6150 Quail Valley Ct. Riverside, CA 92507 (909) 279-9181
Mirachem 500	Mirachem	1034 Saxonhill Drive Cokeysville, MD 21030 (410) 666-8774
PolySpray-Jet 790	PolyChem	P.O. Box 268 Spring Valley, NY 10977 (800) 431-2072
Preferred B&T	Global Diversifie Products	N/A

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